Finite Element Model Of A Helical Swimming Robot in COMSOL Multiphysics

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INTRODUCTION

- Small scale robots for biomedical applications.
- Robot helical shape affects swimming efficiency.
- Microscale hydrodynamics → Low Reynolds Number.

$$R_e = \frac{vL\rho}{\mu}$$

HYDRODYNAMICS IN LOW RE REGIME

- Navier-Stokes and continuity equations are reduced to the Stokes equation.

$$-\nabla p + \mu \nabla^2 u = 0$$
$$\nabla \cdot u = 0$$

- Linear relationship between kinetics and kinematics.

$$\begin{bmatrix} F \\ N \end{bmatrix} = \begin{bmatrix} A & B \\ B^T & C \end{bmatrix} \cdot \begin{bmatrix} U \\ \Omega \end{bmatrix}$$

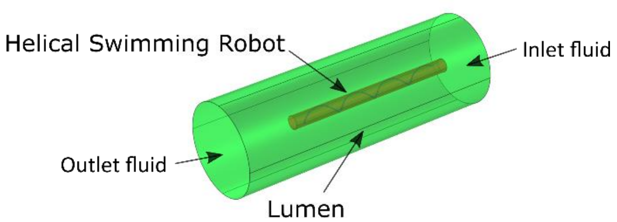
- Matrix coefficients can be estimated from Resistive Force Theory (RFT).

- Drag, thrust and torque can be easily computed in COMSOL Multiphysics®.

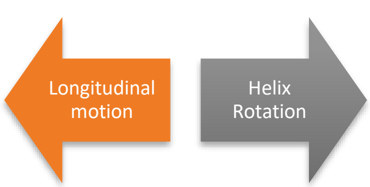
$$F_x = \int_S \sigma_x dS$$
$$N_x = \int_S (z\sigma_y - y\sigma_z) dS$$

MODELLING IN COMSOL MULTIPHYSICS ®

- Implementation of a helical swimming robot inside of a lumen.



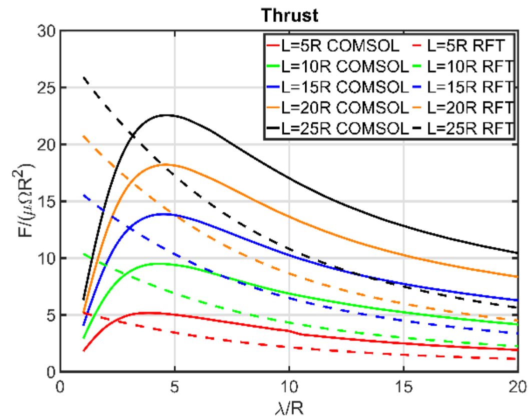
- Low Re number implies that linear and rotational speed contribution are additive. Model is divided into two independent simulations.

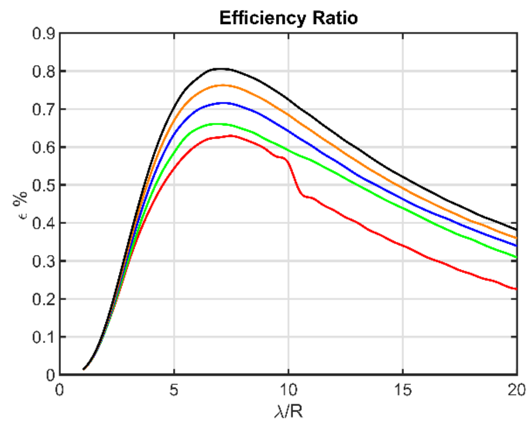


SIMULATIONS AND RESULTS:

- Swimming efficiency is studied for three geometrical parameters:
  - Helix pitch λ.
  - Helix length L.
  - Helix envelope factor α.

- An optimal value is obtained when $\lambda = 7R$ regarding normalized pitch.





CONCLUSIONS

- COMSOL Multiphysics is a better approach to estimate thrust, drag and torque generated by a helical swimming robot.
- Thrust, drag and torque will increase as L increases.
- An optimal in efficiency was obtained when $\lambda = 7R$.
- There is no advantage in using an exponential envelope for the time being.

Acknowledgements

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